AMENDMENTS TO THE SPECIFICATION:

Please replace the Abstract with the following amended Abstract:

A method for designing ~~of~~ a multi-objective least conservative robust controller to control a plant or a process is disclosed. ~~which may be modeled imperfectly. It comprises~~ The method may include a robust analysis step and a robust multi-objective controller synthesis step using Q-parameterization control design technique. In ~~one embodiment of the invention~~ the method, the K-step of standard D-K iteration for mu-synthesis ~~is~~ may be replaced by a Q-parameterization control design step. The Q-step optimization problem formulation ~~comprises~~ include a standard robustness measure and one or ~~a plurality of~~ more other performance measures. ~~During the iteration, the Q-step optimization problem formulation can be changed. In another embodiment, a~~ A controller satisfying a level of robustness measure is first found. Then, a Q-parameterization control design step is performed, such that ~~the~~ one or ~~plurality of the~~ more other performance measures are optimized.~~, while still satisfying a level of robustness measure which is the same with, or slightly traded-off from the previous level of robustness measure. In all embodiments of the invention, if the~~ The robustness measure in the Q-step ~~is~~ may be formulated based on frequency-gridding; as a result, the problematic D-step curve fitting process in standard D-K iteration can be avoided. ~~In addition, a least-conservative non-parametric plant uncertainty weights can incorporated directly without curve-fitting. Therefore the difficulties of curve-fitting and the conservativeness due to curve-fitting in standard D-K iteration can both be eliminated.~~

Please replace paragraph [0005] with the following amended paragraph:

[0005] Robustness is an important issue in many engineering disciplines. In the field of control engineering, robustness against disturbances and model uncertainty is at the heart of control practice. The key part of robust feedback control has been focusing on the effects of plant modeling uncertainty on stability. This is in contrast with optimal control, which usually deals with disturbance rejection while assuming the absence of modeling error. Robust optimal control is a combination of the two, which can keep certain level of disturbance rejection despite the presence of modeling error. If a control design is optimized

only for a nominal model without considering possible modeling error, it can perform far from expectation, since the actual system dynamics is not represented exactly by the nominal model. Conversely, ~~it~~ if a control design is optimized only for maximizing a stability margin without considering the magnitude and inherent structure of the actual modeling error, the resulting system performance can be over conservative, since the actual system dynamics variation is not as large as modeled in the control design stage. In addition, if performance specifications can not be directly specified in the control design problem formulation, it is impractical to expect the resulting system performance can be meet the specifications.

Please replace paragraph [0032] with the following amended paragraph:

[0032] FIG. 4. shows an example design flowchart for one embodiment of the invention, where the control optimization step 450 incorporate standard robustness measure and one or multiple of performance objectives. The method starts with step 410 to define a generalized plant model, as in the prior-art step 310. Then Q-parameterization is performed in step 430, such that the problem formulation is in the form of FIG. 2B and FIG. 2C. Then in step 440, the frequency response of the block-diagonal uncertainty scaling D is optimized frequency-by-frequency, as in the prior-art step 340. If in step 450, the designer chooses the robustness measure to be formulated based on a frequency-by-frequency gridding optimization formulation, then in step 440 , no curve-fitting to the frequency response of D is required; and in step 420 , the frequency response data of the uncertainty weights can be provided without curve-fitting it to a parametric model. Some prior-art publication explaining the procedure to perform this frequency gridding optimization can be found in [B. Rafaely et al, "H_2/H_∞ active control of sound in a headrest: design and implementation," IEEE Trans. Control System Technology, vol. 7, no. 1, January 1999][P. Titterton, "Practical method for constrained-optimization controller design: H_2 or H_∞ optimization with multiple H and/or H_∞ constraints," IEEE Proceedings of ASILO 1996]][A. Lanzon et al "A Frequency Domain Optimisation Algorithm for Simultaneous Design of Performance Weights and Controllers in mu-Synthesis", Proceedings of the 38th IEEE Conference on Decision and Control, Vol. 5, pp. 4523-4528, Phoenix, Ariz., USA, December 1999] [K. Tsai et al, "DQIT: μ-synthesis without D-Scale Fitting," American Control Conference 2002, pp. 493-498]. If the robustness measure is formulated based on non-frequency gridding approaches, then parametric models

in step 420 and step 440 are still required. In step 450, the control optimization formulation not only includes the robustness measure, but also one or multiple performance objectives. The trade-off between these performance objectives and the improvement of the robustness measure can be adjusted by modified the control optimization formulation in each iteration. As an example, a control optimization problem can be formulated as: minimize $\{(1-rho)*sigma(DH(Q)D^{-1}))+rho*f_0(H(Q))\}$ for a set of selected frequencies, with respective to the free controller design parameter Q, subject to: $\{f_k(H(Q))<0\}$ where k is a nonnegative integer. Here $H(Q)$ represents system 130, $sigma(DH(Q)D^{-1}))$ represents the upper bound of μ as the robustness measure, f_0 is a performance objective such as maximum control effort, f_k represents one or multiple performance constraints, such as the noise amplification of one of the input-output channels, and rho is a weighting factor between 0 and 1, which can be adjusted at each iteration to enforce the optimization weights more on the robustness measure or the performance objective f_0. Many other variations from this example optimization formulation are possible. The D-step 440 and Q-step 450 are iterated until a decision is made to stop the iteration, commonly when as performance requirement has been met, or when there is no more performance improvement with more iterations.
REDUCING ROBUST STABILITY CONSERVATISM OF MULTI-OBJECTIVE
~~ONTROL~~ CONTROL

Please replace paragraph [0033] with the following amended paragraph:

[0033] FIG. 5. shows an example design flowchart for another embodiment of the invention, where step 550 shows one or multiple performance objectives can be simultaneously optimized while satisfying a predetermined robustness measure. The method starts with step 510 to define a generalized plant model, as in the prior-art step 310. Then Q-parameterization is performed in step 530, such that the problem formulation is in the form of FIG. 2B and FIG. 2C. In step 540 a Q-step and a D-step iteration is performed until a robustness measure is met. In fact, in one variation step 530 and step 540 can be replaced by the prior-art D-K iteration, followed by a Q-parameterization step before step 550. In step 550, the control optimization formulation includes one or multiple performance objectives or constraints, and the robustness measure intending to keep the level of robustness measure obtained by step 540. As an example, suppose from step 540 an upper bound of μ is found to be gamma0. A control

optimization problem can be formulated as: minimize {f (Q)for a set of selected frequencies, with respective to the free controller design parameter Q, subject to {sigma(DH(Q)D $^{-1}$))<gamma1, and f_k(Q)<O, k=1, 2, 3 . . . }. Here H(Q) represents system 130, sigma(DH(Q)D $^{-1}$)) represents the upper bound of μ as the robustness measure, f_0 is a performance objective such as maximum control effort, f_k represents one or multiple performance constraints, such as the noise amplification of one of the input-output channels, and gamma0 is the same or slightly adjusted to be larger than gamma0 obtained from step 540 , such that the optimization process can have enough feasible set in order to satisfy the performance constraints f_k(Q)<0. Many other variations from this example optimization formulation are possible. This method is useful to improve the conservatism of the previously described prior-art Q-parameterization control design method where the inherent structure of the uncertainties are commonly ignored by simply formulating sigma(H(Q)) which is equivalent with a un-scaled H_∞ constraint. FIG. 6 shows an example flowchart ~~two~~ to compare the method in this embodiment and the prior-art method. Numerical examples can be found in [K. Tsai, Design of Feedforward and Feedback Controllers by Signal Processing and Convex Optimization Techniques, chapter 3], which is claimed for the invention.

Please replace paragraph [0034] with the following amended paragraph:

[0034] If in step ~~5 50~~ 550, the designer chooses to use Q-optimization as in step 530, and formulate the robustness measure based on a frequency-by-frequency gridding optimization formulation, then in the iteration step ~~5 40~~ 540, no curve-fitting to the frequency response of D is required; and in step ~~5 20~~ 520, the frequency response data of the uncertainty weights can be provided without curve-fitting it to a parametric model. Some prior-art publication explaining the procedure to perform this frequency gridding optimization can be found in [B. Rafaely et al, "H_2/H_∞ active control of sound in a headrest: design and implementation," IEEE Trans. Control System Technology, vol. 7, no. 1 , January 1999][P. Titterton, "Practical method for constrained-optimization controller design: H_2 or H_∞ optimization with multiple H_2 and/or H_∞ constraints," IEEE Proceedings of ASILO 1996]][A. Lanzon et al "A Frequency Domain Optimisation Algorithm for Simultaneous Design of Performance Weights and Controllers in mu-Synthesis", Proceedings of the 38th IEEE Conference on Decision and Control, Vol. 5, pp. 4523-4528, Phoenix, Ariz., USA, Dec 1999] [K. Tsai et al, "DQIT: μ-

synthesis without D-Scale Fitting," American Control Conference 2002, pp. 493-498]. If the robustness measure is formulated based on non-frequency gridding approaches, then parametric models in step ~~5-20~~ 520 and step ~~5-40~~ 540 are still required.

D-Q ITERATION WITH NONPARAMETRIC PLANT UNCERTAINTY WEIGHTS INCORPORATED DIRECTLY WITHOUT CURVE-FITTING

Please replace paragraph [0035] with the following amended paragraph:

[0035] As another embodiment, when there is no need to incorporated multiple performance objectives with a robustness measure, but it is desired to reduce the conservatism by reducing the modeling error of the plant uncertainty from its experimental data, step 450 can be substituted with "Optimize Q while fixing D, based on frequency gridding to formulate robustness measures, with or without other performance measures". In step 420, the frequency response of the plant uncertainty can be provided directly from a estimate of the least conservative nonparametric model error weight. One of the prior-art publications showing a method to perform the estimation is [H. Hindi et al, "Identification of Optimal Uncertainty Models from Frequency Domain Data," Proceedings of the IEEE Conference on Decision and Control, 2002]. It should reduce the conservatism due to the use of a simplified and conservative model error weighting function of the standard D-K iteration.

D-Q ITERATION WITH ROBUSTNESS MEASURE FORMULATED WITH DECISION VARIABLES BEING THE FREQUENCY RESPONSE OF Q

Please replace paragraph [0037] with the following amended paragraph:

[0037] With this optimization formulation, another embodiment to improve the prior-art D-K iteration in FIG. 3 is to substitute step 450 with "Optimize Q while fixing D, based on frequency gridding to formulate robustness measures, with or without other performance measures" and the frequency gridding formulation is based using the frequency response of the free controller design parameter Q as the decision variables, with periodical causality constraints imposed on the decision variables.

A COMPARISON OF D-K ITERATION WITH D-Q ITERATION WITHOUT D-FITTING